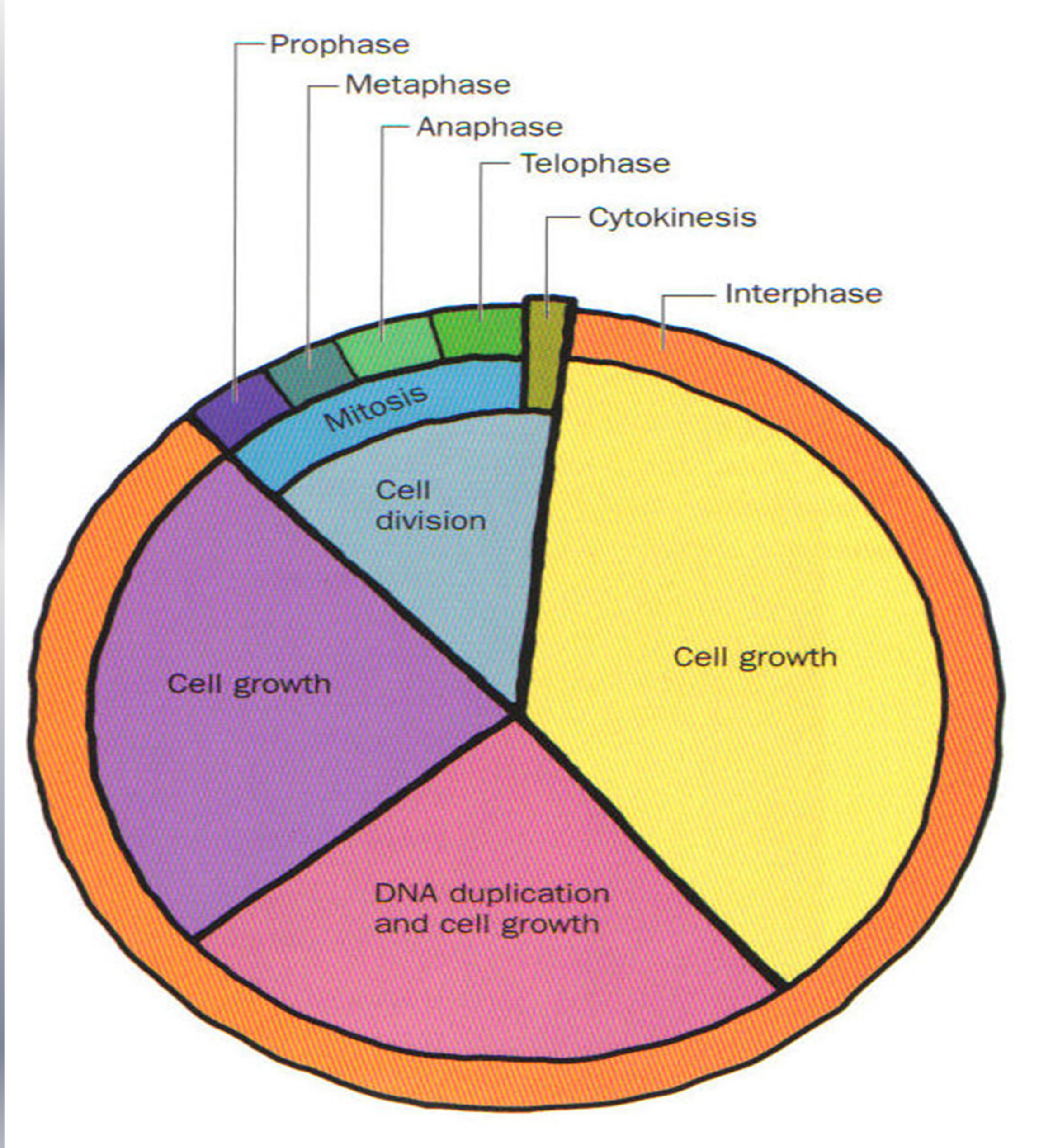
CELL DIVISION

- ***Cell division*** =
  - The formation of 2 daughter cells from a single parent cell
- New body cells necessary for growth and tissue repair are formed through ***mitosis***
- Sex cells necessary for reproduction are formed through ***meiosis***
- ***Apoptosis*** =
  - Programmed cell death
- Coordination of cell division and apoptosis maintains cell numbers

- Somatic cells (body cells)
  - ***<u>Diploid</u>*** = contains 2 sets of chromosomes
  - Human somatic cells have 46 chromosomes
  - Organized to form 23 pairs of chromosomes
    - 1 pair are sex chromosomes
      - XX = female
      - XY = male
    - Remaining 22 pairs are called ***<u>autosomes</u>***
  - Formed by mitosis
- Reproductive cells (sperm and egg)
  - ***<u>Haploid</u>*** = contains 1 set of chromosomes
  - Union of sperm and egg restores the diploid state
  - Formed by meiosis

Cell Cycle

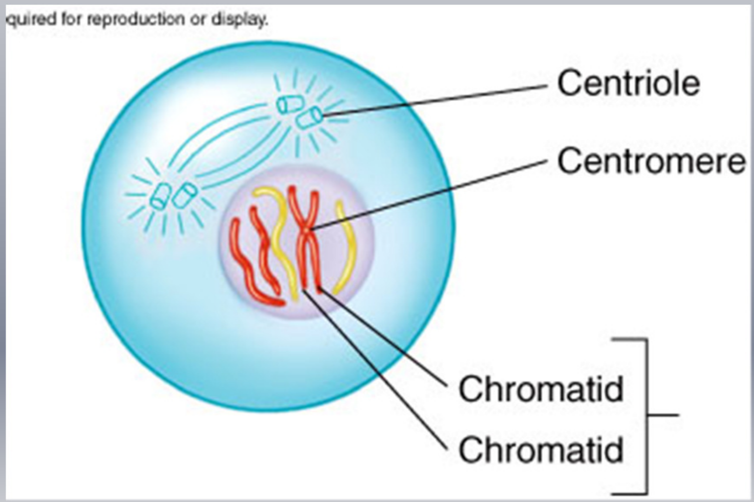
- 2 major stages in the cell cycle
  - Interphase (not dividing)
    - Gap phases (G_1 and G_2)
      - Proteins and lipids are produced
    - Synthesis phase (S)
      - Chromosomes are copied
  - Mitosis (dividing)
    - Produces 2 identical cells that have the same number and types of chromosomes as the parent cell
    - Broken down into 4 phases


Prophase
Metaphase
Anaphase
Telophase
Cytokinesis
Interphase
Mitosis
Cell division
Cell growth
Cell growth
DNA duplication and cell growth

Mitosis

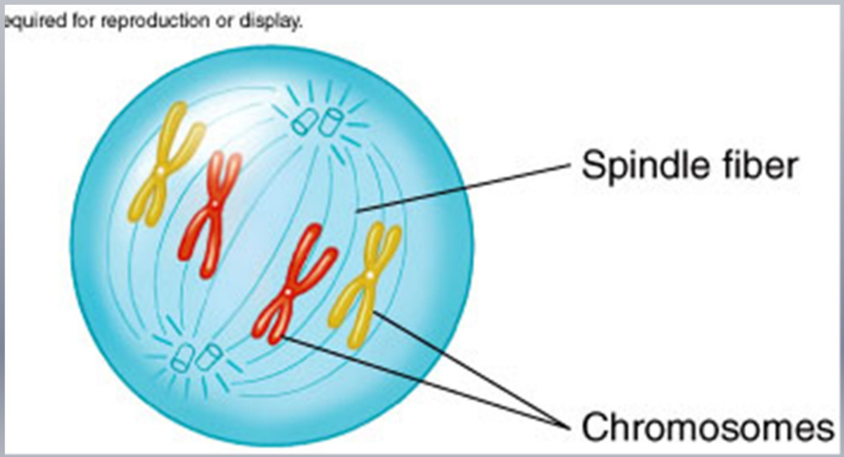
1. Prophase

- First and longest phase of mitosis
- DNA coils tightly and chromosomes become visible
  - Chromosomes form 2 identical strands called ***sister chromatids*** =
    - Identical copies of the same chromosome
  - Sister chromatids are attached at ***centromere***
- Centrioles appear and spindle assembles
- Nuclear envelope breaks down



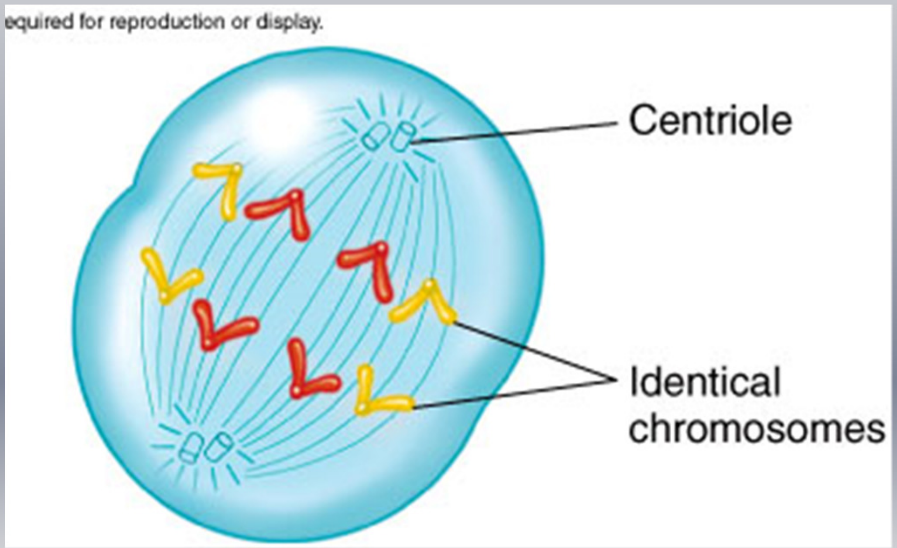
2. Metaphase

- Second phase of mitosis
- Shortest phase
- Chromosomes line up across middle of cell

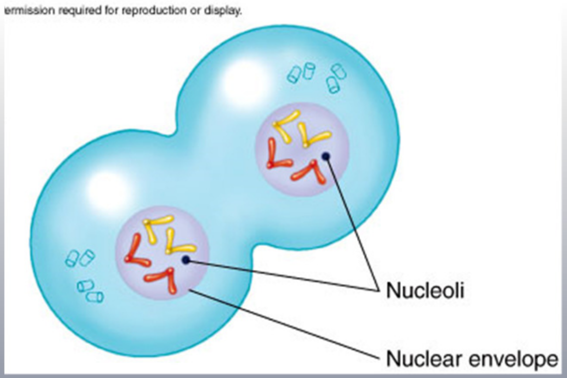


3. Anaphase

- Third phase in mitosis
- Centromeres part
- Chromatids separate and move toward the centrioles at each end of the cell



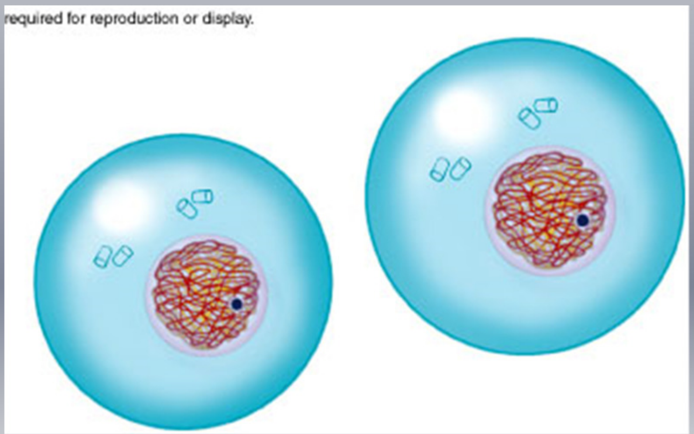
4. Telophase



- Fourth phase of mitosis
- Chromosomes disperse (half on each side of cell)
- Spindle disassembles
- Nuclear envelope reforms (one at each end)

Followed by ***<u>cytokinesis</u>*** =

- Division of the cytoplasm and its components



Control of the Cell Cycle

- DNA damage checkpoint
  - Pauses cell cycle while proteins repair damaged DNA
- Apoptosis checkpoint
  - Proteins called survivins override signals telling the cell to die so cell division, rather than cell death, occurs
- Spindle assembly checkpoint
  - Oversees construction of spindle and the binding of chromosomes to it

- Factors outside the cell that affect cell's mitosis clock
  - Crowding
  - Hormones
  - Growth factors
- Internal triggers of mitosis
  - Interactions of 2 types of proteins
    - Cyclins
    - Kinases

- ***Telomeres*** =
  - Chromosome tips
  - Like cellular "fuses" that burn down as pieces are lost from the ends
  - Length of telomere determines how many more times the cell can divide

- ***Telomerase*** =
  - Enzyme that adds DNA to chromosome tips
  - Produced by
    - Sex cells (eggs, sperm)
    - Cancer cells
    - A few types of normal cells that must continually supply new cells
      - Ex-bone marrow cells

Meiosis

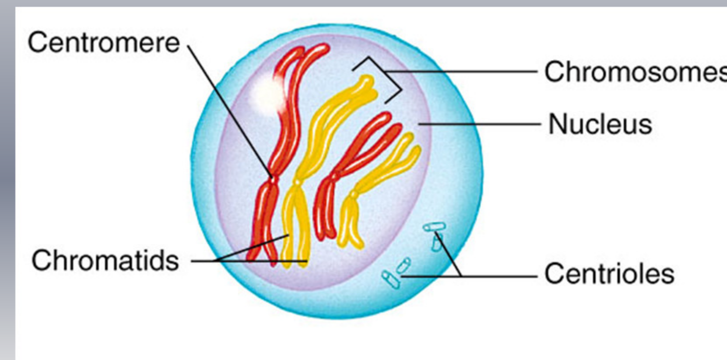
- ***Meiosis*** =
  - Cell division that halves the number of chromosomes to form haploid gametes
  - Mixes up trait combinations, providing genetic diversity

- Chromosomes pairs are called ***homologs***
  - One comes from mom and one comes from dad
  - Have same genes in same order but may carry different alleles (variants) of the same gene

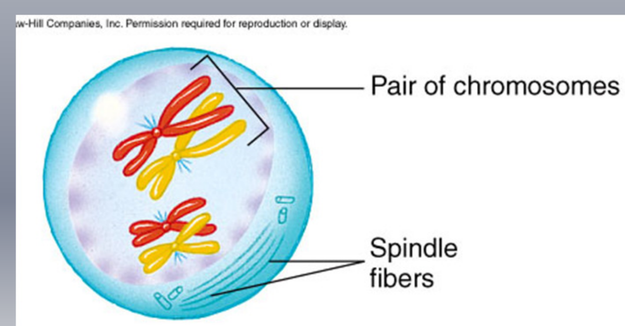
- Interphase
  - DNA is replicated
- 2 divisions of genetic material
  - Reduction division (Meiosis I)
    - Reduces number of replicated chromosomes from 46 to 23
  - Equational division (Meiosis II)
    - Produces 4 cells from the 2 cells formed in the first division by splitting the replicated chromosomes

Prophase I

- Replicated chromosomes condense and become visible

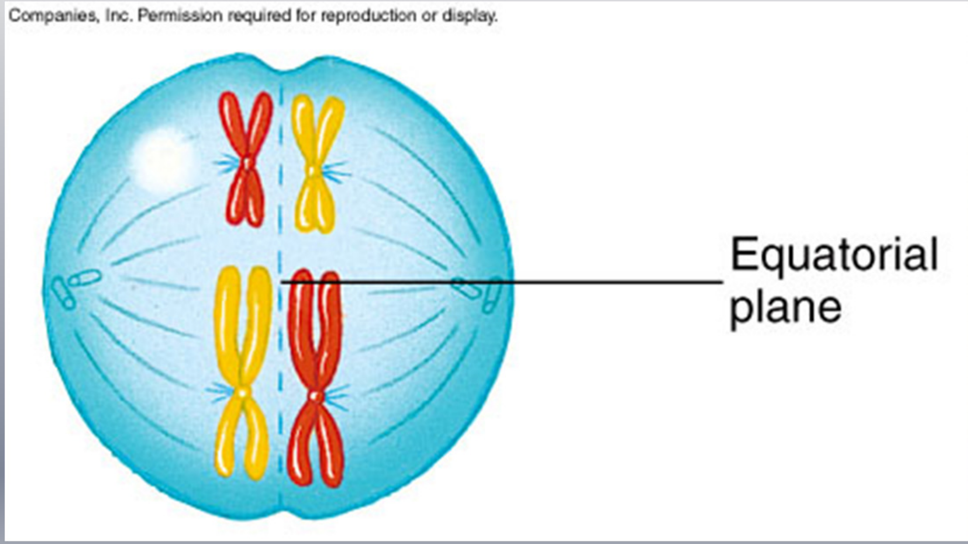


- Spindle forms
- Nuclear envelope fragments
- ***<u>Synapsis</u>*** =
  - Homologs line up next to one another
- ***<u>Crossing over</u>*** =
  - Homologs exchange parts



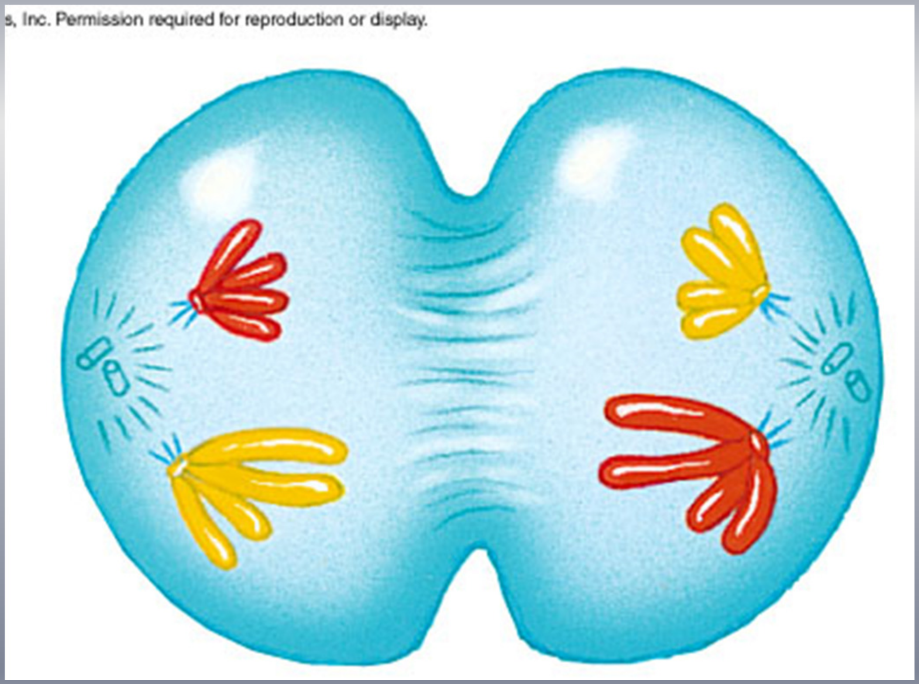
Metaphase I

- Homologs align down the center of the cell
- ***<u>Independent assortment</u>*** =
  - Random alignment of homologs



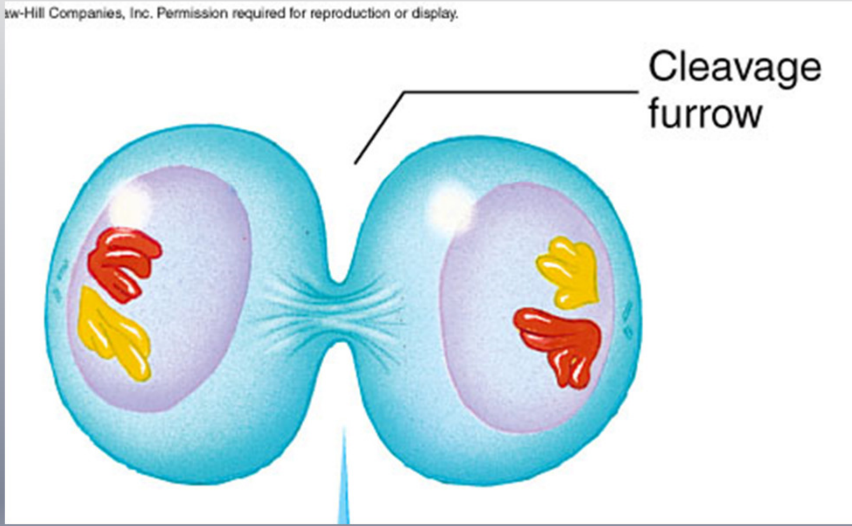
Anaphase I

- Homologs separate to opposite poles of cell



Telophase I

- Homologs finish moving to opposite poles
- Nuclear envelopes partially assemble around chromosomes on either side of cell
- Spindle disappears
- Cytokinesis divides cell into two



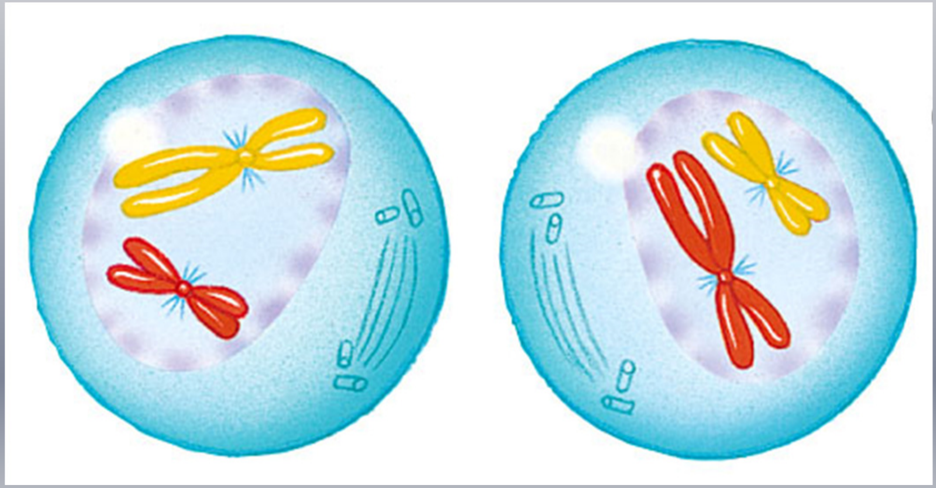
Results of Meiosis I

- Haploid set of still-replicated chromosomes at each end of stretched-out cell
- Centromeres of each homolog remain together

- Second Interphase
  - Proteins are manufactured
  - NO DNA replication

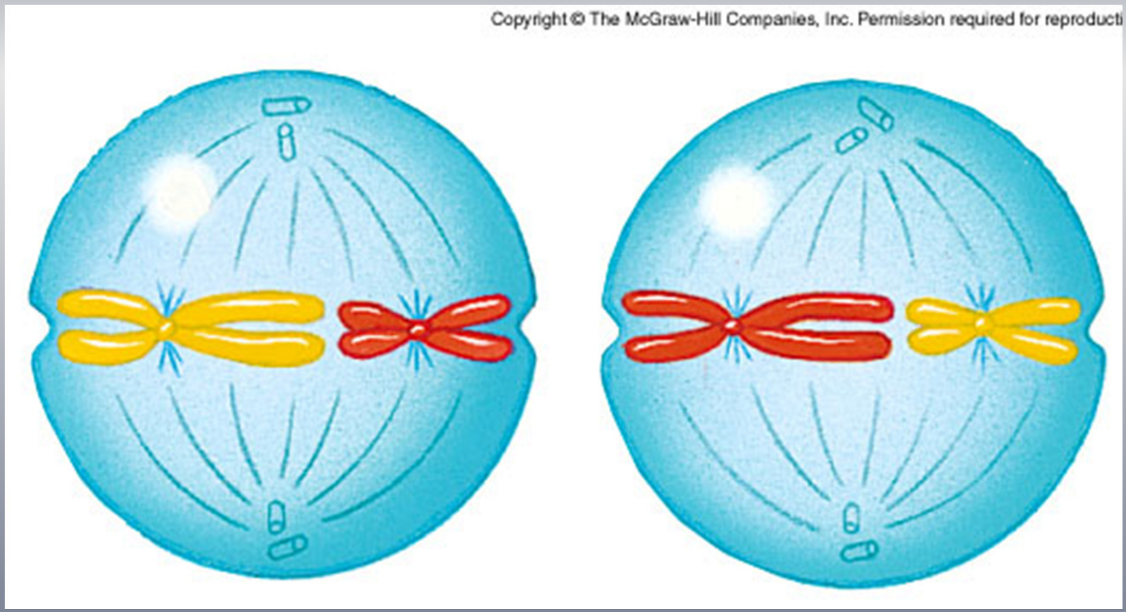
Prophase II

- Chromosomes are again condensed and visible
- Nuclear envelope fragments
- Spindle forms and fibers attach to both chromosomes



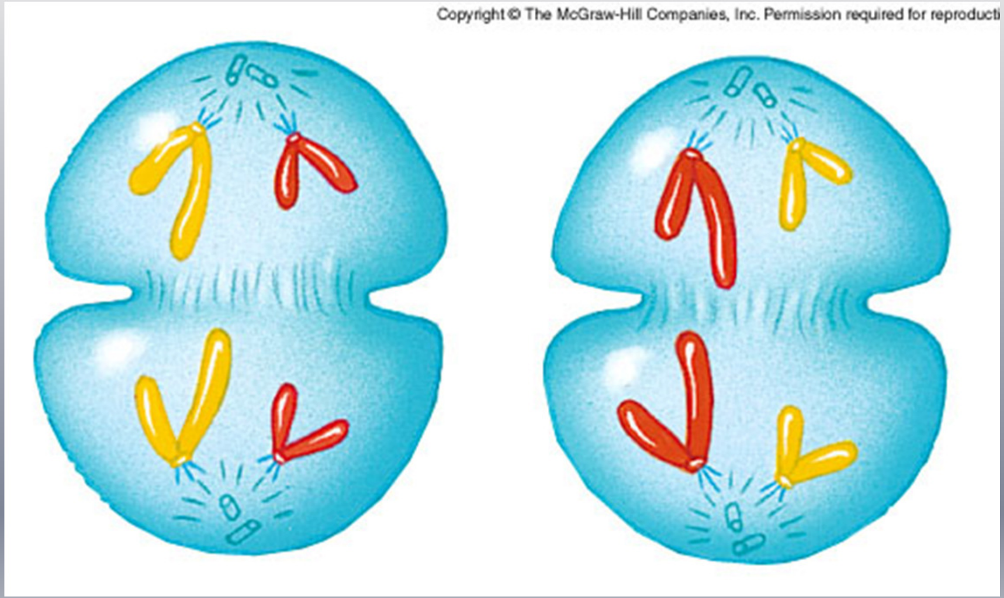
Metaphase II

- Replicated chromosomes align down center of cell



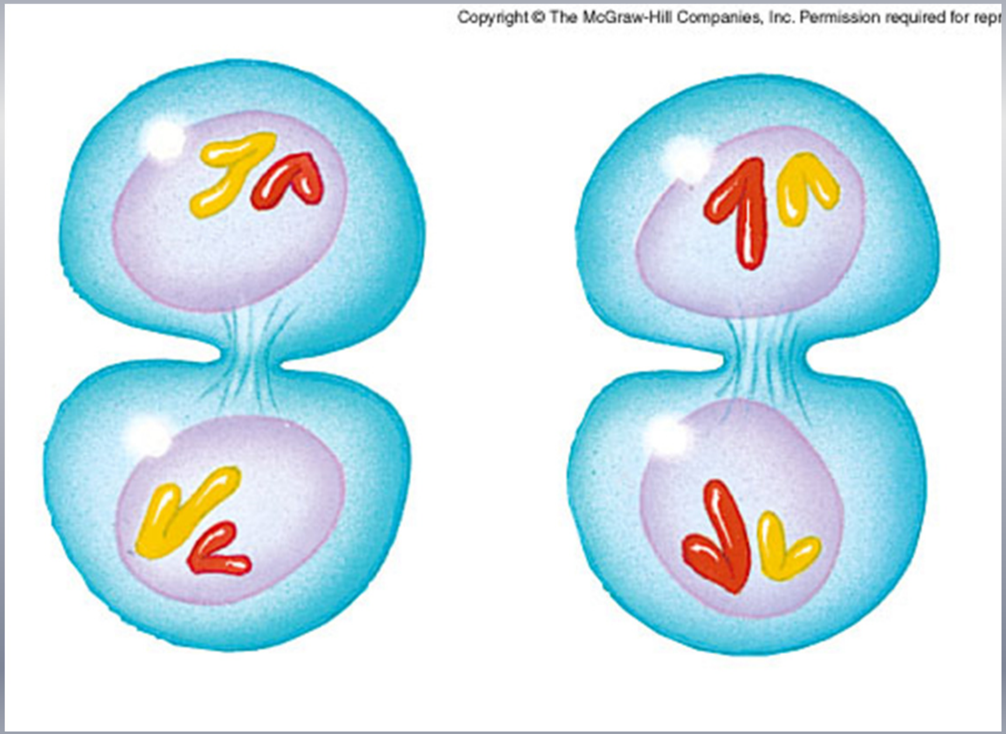
Anaphase II

- Centromeres part
- Sister chromatids separate and move to opposite poles



Telophase II

- Nuclear envelopes form around 4 nuclei
- Spindle disappears
- Cytokinesis divides cells into 4
- Result:
  - 4 cells
  - Nonidentical
  - Haploid



Mitosis	Meiosis
One division	Two divisions
2 daughter cells per cycle	4 daughter cells per cycle
Daughter cells genetically identical	Daughter cells genetically different
Chromosome # of daughter cells same as that of parent cell (2n)	Chromosomes # of daughter cells half that of parent cell (1n)
Occurs in body cells	Occurs in reproductive cells
Occurs throughout life cycle	In humans, complete after sexual maturity
Used for growth, repair, and asexual reproduction	Used for sexual reproduction, producing new gene combinations

Stem Cells

- ***Stem cells*** =
  - Produce daughter cells that retain the ability to divide as well as daughter cells that specialize
  - Can self-renew
  - Less specialized than progenitor cell that descends from it

- ***Progenitor cells*** =
  - Cells whose descendants can follow any of several developmental pathways, but not all
  - Cannot self-renew
  - Give rise to more specialized daughter cells

- Both renew tissues by producing cells as body grows or cells are lost

3 General Sources of Stem Cells

1. Embryonic stem (ES) cells
   - Created in lab dish using cells from region of very early embryo called inner cell mass (ICM)
   - ICM cells come from
     - "Left-over" embryos from fertility clinics
     - Nuclear transfer
       - » Nucleus from somatic cell is transferred to egg cells that had its own nucleus removed

2. Induced pluripotent stem (iPS) cells
   - Somatic cells that are genetically reprogrammed to differentiate into any of several cell types

3. “Adult” stem cells
   - Tissue specific or somatic stem cells
   - Self-renew but most are multipotent
     – Give rise to only a few types of specialized daughter cells

4 Basic Stem Cell Applications

1. Drug discovery and development
   - Drugs are tested on cells produced by stem cell cultures

2. Observe earliest signs of disease
   - Ex-Lou Gehrig’s disease
   - New treatments are being discovered

3. Create tissues and organs
   - To study
   - For use in implants and transplants
     - Ex-bone marrow transplant

4. Possibility to introduce reprogramming proteins directly into body to simulate stem cells in their nature niches
   - If we understand the signals, we might not need the cells